D-C and Low Frequency Lab.

HERMACH ENGELHARD TRANSFER VOLTAMMETER
MODEL NO. 34600 = C

INSTRUCTION MANUAL

ENGELHARD
INDUSTRIES, INC.

INDUSTRIAL EQUIPMENT DIVISION
INSTRUMENTS & SYSTEMS SECTION
850 PASSAIC AVE., EAST NEWARK, HARRISON P.O., N.J.

MP MASTER
MA31601

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Figure 1. AC Transfer Volt-Ammeter, Hermach-Engelhard Model C

SECTION I

USE AND MAINTENANCE

1. GENERAL.

2. This manual describes the use, maintenance, and parts breakdown for AC Transfer Volt-Ammeter, Hermach-Engelhard Model C, figure 1, manufactured by Engelhard Industries, Inc., Industrial Equipment Division, Instruments and Systems Section, 850 Passaic Avenue, East Newark, New Jersey.

3. The AC Transfer Volt-Ammeter, Hermach-Engelhard Model C referred to in this manual as volt-ammeter is a very precise AC and DC voltage and current measuring instrument. The accuracy of the volt-ammeter is such that it can be used not only to measure voltages and currents but to calibrate other AC and DC measuring instruments. The volt-ammeter uses the transfer principle to measure AC voltages or AC and DC currents. The transfer principle is to heat a thermocouple with the unknown voltage or current and reheat the thermocouple to the same temperature with an internal DC source, and then measure the DC with a potentiometer. To measure DC voltages, the volt-ammeter is used as a volt-box.

4. DESCRIPTION.

5. The volt-ammeter is enclosed in a wooden case approximately 9 inches high, 19 inches wide, and 15 inches deep, including the handle. The volt-ammeter weights 32 pounds. All controls and indicators are located on the front panel, which is protected in transit and storage by the hinged wooden cover. No external power is required and no test leads are supplied with the volt-ammeter. Power for the volt-ammeter is supplied by internal batteries. The batteries and thermal converter, which are under the instruction plate, can easily be replaced by removing the four thumb screws securing the instruction plate.

6. ASSOCIATED EQUIPMENT.

7. The equipment listed in figure 2 is used in conjunction with the volt-ammeter, but is not furnished with the volt-ammeter. Only the potentiometer is essential for all measurements. The galvanometer and milliammeter are needed only when determining AC - DC difference of other measuring instruments.

Description	Use
Precision potentiometer with a scale 0 to 1.5 volts. Accuracy 0.01 to 0.05%.	Determines the value of current or voltage being measured.
Galvanometer: galvanometer with a sensitivity of approximately 1.5 microvolts per millimeter with a critical damping resistance of approximately 30 ohms. With a galvanometer of this sensitivity, AC - DC differences as small as 0.02 percent can be detected.	Increases the accuracy when determining the AC - DC difference of other measuring instruments.
Milliammeter: milliammeter to measure to 1.5 milliamperes DC at 2 percent accuracy.	Increases the ease of determing the AC - DC difference of other measuring instruments.
High Frequency Thermal Converters.	Extends the frequency range of the volt-ammeter into the megacycle region. Used only for voltage measurement above 50 KC.
Connecting Cable: Engelhard Industries Part No. 35600C.	Connects high frequency thermal converter to the volt-ammeter.

Figure 2. Associated Equipment Required but not Supplied

Voltage Ranges:	1500 - 600 - 300 - 150 - 60 - 30 - 15 - 6 - 3 - 1.5 - 0.5
Current Ranges: (Amperes)	25 - 10 - 5 - 2.5 - 1.0
(Milliamperes)	500 - 250 - 100 - 50 - 25 - 7.5
Frequency Range for 1500 volt, 10 and 25 ampere ranges	5 - 20,000 CPS
Frequency Range for all other ranges	5 - 50,000 CPS
All scales are capable of measuring DC except the 0.5 V and 1.5 V ranges where the potentiometer should be used directly.	
Accuracy (percent of full scale without any correction factors)	±0.05%
Voltage Ranges Burden:	7.5 MA (133 ohms per volt)
Current Ranges Burden:	0.5 V
Power Requirement:	Mercury Cell Pack 1.34 V and 2.68 V Dry Cell, size D 1.5 V

Figure 3. Volt-Ammeter Specifications

8. PRINCIPLE OF OPERATION (figure 5).

9. The AC voltage or AC or DC current to be measured is proportionally reduced by precision multipliers or shunts selected by the voltage and current range switches and checked by the panel meter for magnitude. The accurately known proportional voltage or current is then used to heat a resistance wire which is part of a thermal converter. The thermal converter is essentially a resistance wire which is heated proportionally to the applied voltage or current and a thermocouple which, when heated by the resistance wire, develops a voltage proportional to the resistance wire temperature. The voltage from the thermocouple is now balanced out on a galvanometer by an internal voltage. This internal voltage acts as a memory or reference while the unknown voltage is removed and a second internal voltage is applied to the thermal converter resistance wire. This second internal DC voltage is adjusted to balance out the first internal DC voltage, which acted as the memory or reference voltage. Null is indicated on the galvanometer. This second internal voltage is then equal to the unknown reduced value of the AC voltage or AC or DC current. Then the second internal DC voltage is measured, using the external potentiometer. The value on the potentiometer dial multiplied by the range switch scale factor will be the actual value of the unknown voltage or current.

10. For DC voltage measurements the thermal converter is not used. The voltage is proportionally reduced by a voltage divider and this reduced voltage is then applied to the potentiometer, and the value of the potentiometer reading multiplied by the range switch scale factor will be the value of the unknown DC voltage.

11. If it is desired to extend the frequency range of the volt-ammeter beyond the frequency limit of 50KC, a series of external accessory high frequency thermal converters can be attached to the HFTC jack of the volt-ammeters. These high frequency thermal converters (hereinafter referred to as HFTC) will measure voltages at frequencies up to 30 megacycles with an accuracy of 0.5%. The extended frequency range of these units makes it necessary to use a number of high frequency thermal converters to cover the range of voltage measurements from 0.6 to 200 volts.

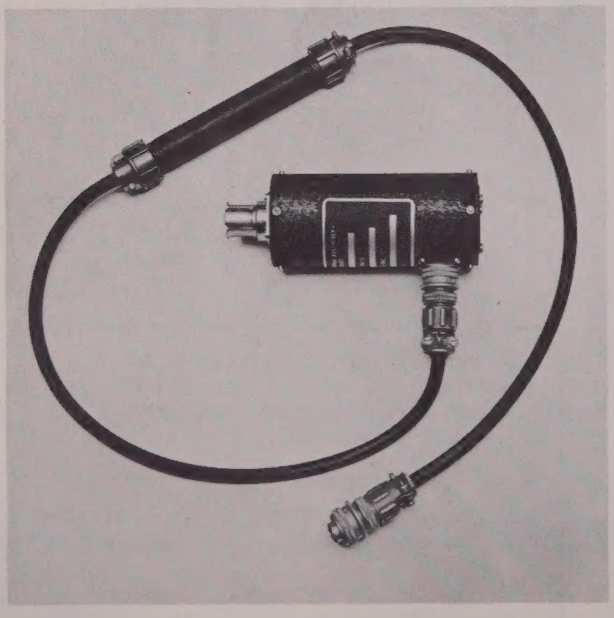


Figure 4. Typical HFTC and Connecting Cable

Index No.	Voltage Range	HFTC Part Number	Accuracy % Full Scale (To 30 MC)	Current Drain (MA)
1	0.6 to 1.4	34970-1	0.5	5
2	1.2 to 3	34970-3	0.5	5
3	2 to 5	34970-5	0.5	5
4	4 to 10	34970-10	0.5	5
5	8 to 20	34970-20	0.5	10
6	20 to 50	34970-50	0.5	10
7	40 to 100	34970-100	0.5	10
8	80 to 200	34970-200	0.5	10

Figure 5. HFTC Specifications

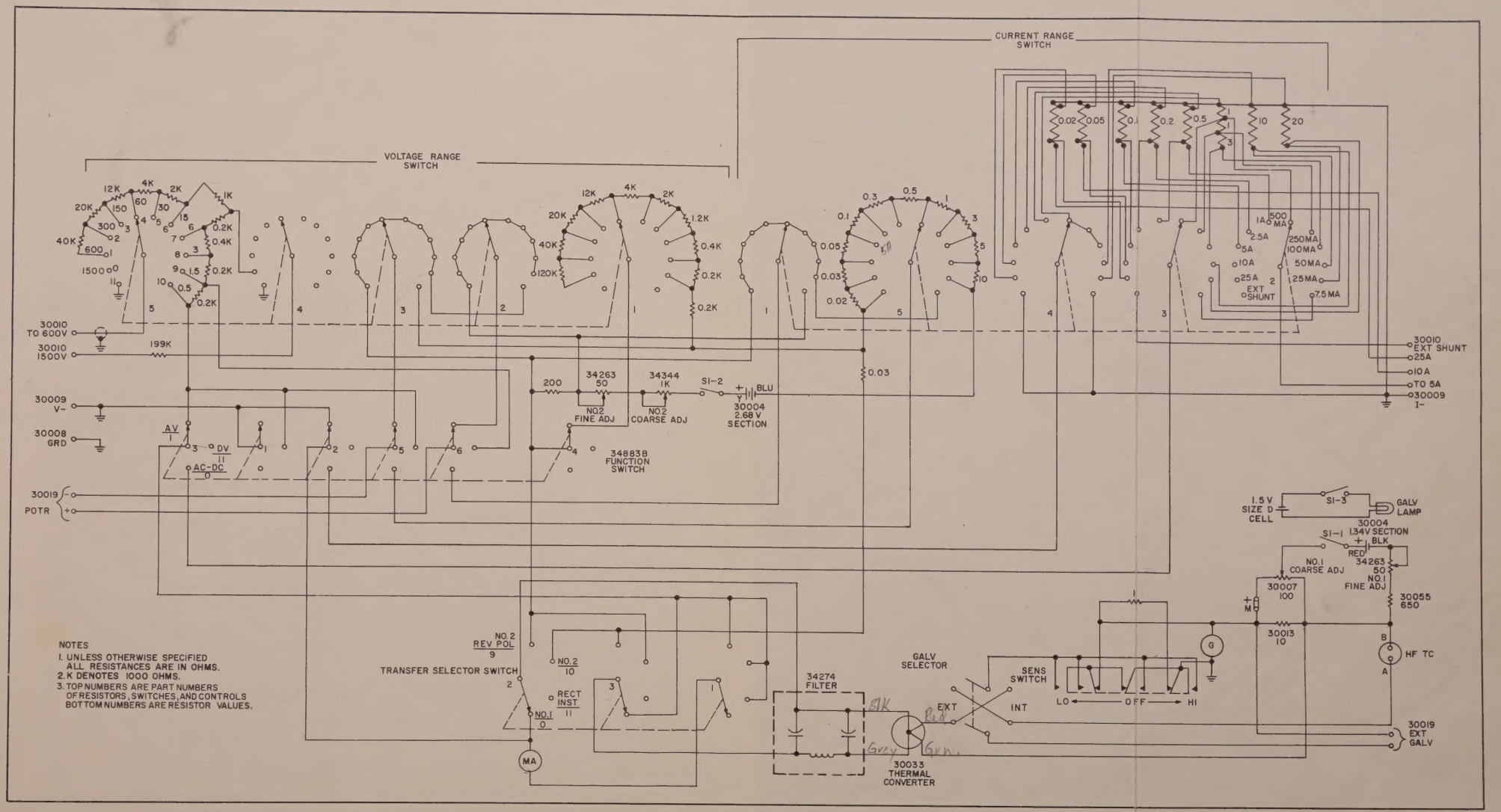


Figure 6. Volt-Ammeter Schematic Diagram

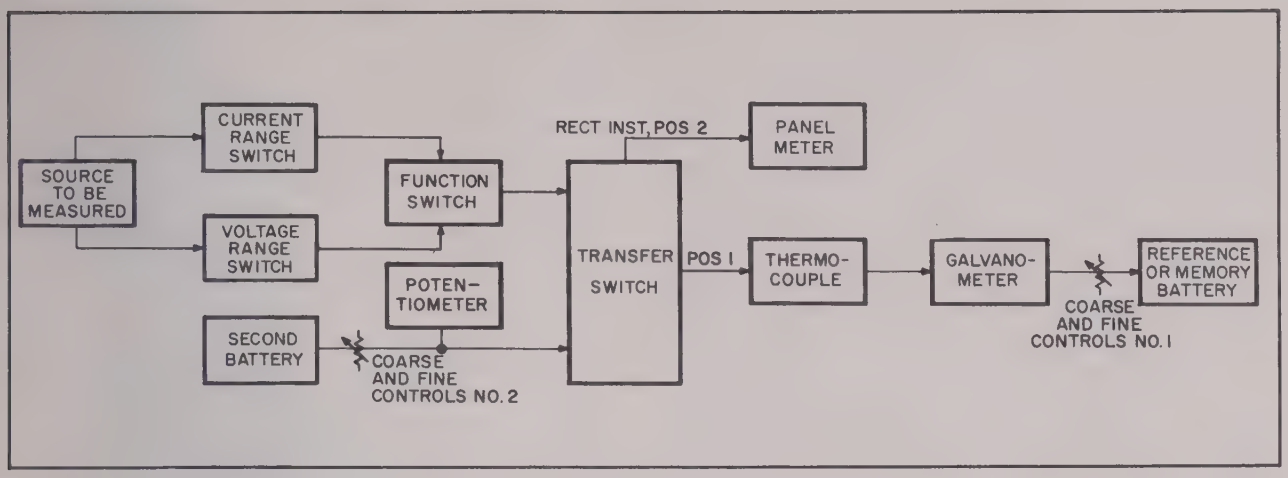


Figure 7. Volt-Ammeter Block Diagram

12. THEORY OF OPERATION.

13. The volt-ammeter is a thermoelectric transfer instrument using an internal thermal converter as a transfer element. (See figure 6.) The thermal converter consists of a heater wire and an insulated thermocouple. The heater wire attains a temperature which depends on the RMS value of the heating current, and the thermocouple translates this temperature into a DC voltage. The response of the thermocouple can, therefore, be given by:

Equation (1): $e = f(i)$

where e is the thermocouple output and i is the RMS value of the heating current. Equation (1) applies over an extremely wide frequency range and, therefore, makes possible the measurement of AC voltage and current over a wide frequency range through the use of specially designed series and/or parallel resistors with the thermoelement.

14. AC VOLTAGE MEASUREMENT. For AC voltage measurements the volt-ammeter is connected as shown in figure 8. The AC voltage Va is applied across the heater Rh through multiplier resistor Rm, with the transfer switch in position 1. The output of the converter is balanced out manually by adjusting internal power source Vb. The balance is indicated on galvanometer G. The transfer switch is then changed to position 2, which connects the heater across a second internal DC source. The heater current is adjusted in this position until the galvanometer G is nulled again.

15. The voltage drop Vp, across resistor Rp, is obtained through an external potentiometer and multiplied by a constant (the factor on the range switch) to render the AC voltage Va. Referring to figure 8 the following relations can be obtained:

Equation (2): $Va = Ia\,(Rm + Rh)$
Equation (3): $Vp = Id\,Rp$
Equation (4): $Ia = Id \dfrac{R'm}{(Rh + R'm)}$, at balance

combining equations 2, 3 and 4, Va can be expressed in terms of Vp:

Equation (5): $Va = \dfrac{Vp}{Rp} \cdot \dfrac{R'm\,(Rm + Rh)}{(R'm + Rh)}$

If R'm is made equal to Rm in equation 5 it should be noted that terms containing Rh are eliminated and Va is given by:

Equation (6): $Va = Vp \dfrac{Rm}{Rp}$

This compensating method is used in the volt-ammeter and makes the measurements independent of the heater resistance Rh and any errors which may be introduced due to changes in its value. The quantity $\frac{Rm}{Rp}$ is selected to give a simple multiplying factor which is indicated on the instrument panel adjacent to the positions of the voltage selector switch.

16. AC AND DC CURRENT MEASUREMENT. To measure AC and DC currents, the thermal converter is connected as shown in figure 9.

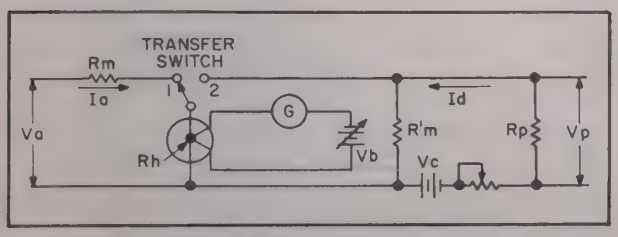


Figure 8. AC Voltage Measurements

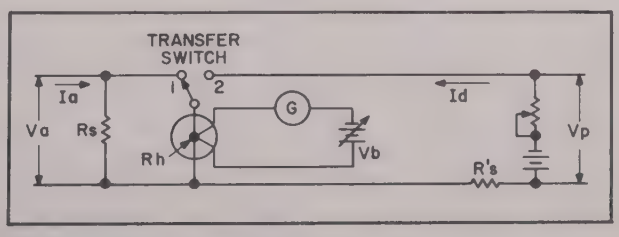


Figure 9. AC and DC Current Measurements

The AC or DC current flows through the shunt Rs and the heater Rh when the transfer switch is in position 1. The galvanometer G is nulled through manipulating the internal DC source Vb. The transfer switch is then moved to position 2 and the second internal DC voltage source is adjusted to regain the galvanometer null. Under this condition, voltage Vp is measured with an external potentiometer and multiplied by a simple factor to render the AC current Ia. This multiplying factor is indicated on the instrument panel adjacent to the current selector switch, and its value can be obtained from the following relationships.

Equation (7):

$$Va = Ia \frac{Rs \cdot Rh}{(Rs + Rh)} = Vp \frac{Rh}{(R's + Rh)}, \text{ at balance}$$

Equation 7 can be simplified to render Ia in terms of Vp as follows:

Equation (8): $Ia + Vp \frac{(Rs + Rh)}{Rs\ (R's\ Rh)}$

Again, the resistance values are chosen such that Rs = R's, which reduces equation 8 to:

Equation (9): $Ia = Vp \cdot \frac{1}{Rs}$

17. Equation 9 shows that Ia is independent of Rh and is obtained by multiplying Vp by the factor $\frac{1}{Rs}$, which is selected to be a round number.

18. DC VOLTAGE MEASUREMENT. The measurement of DC voltages is performed with the instrument used as a volt-box. The thermal converter is not used for this measurement and the external potentiometer is connected directly across a portion Rp of the multiplier resistor Rm. (See figure 10.) Under this condition, it is evident that

Equation (10): $Va = Vp \frac{Rm}{Rp}$

rendering the same multiplying factors for DC voltage measurements as for AC voltage measurements.

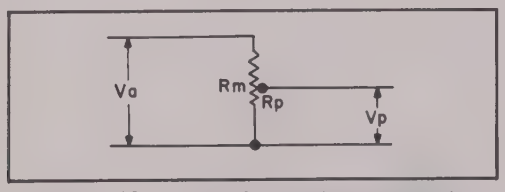
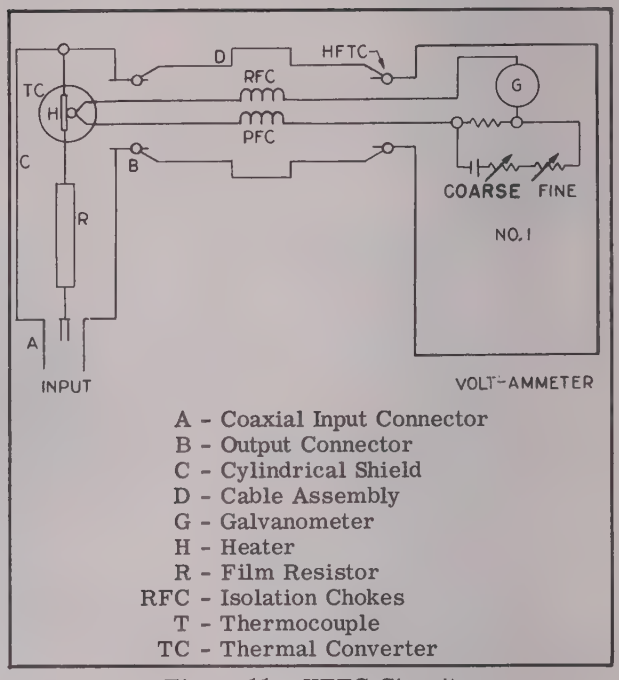


Figure 10. DC Voltage Measurements

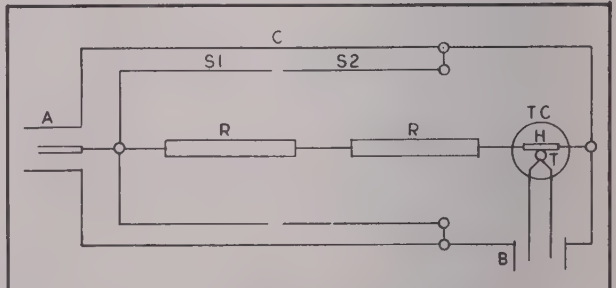
19. VOLTAGE MEASUREMENTS ABOVE 50 KC. The HFTC's employ the direct transfer principle. (See figures 11 and 14). The radio frequency voltage under test passes through the dropping resistor (R) and the heater (H) of the vacuum thermal converter (TC). The radio frequency current raises the temperature of the heater and also heats the thermocouple (T) which is attached to the heater with a small ceramic bead. The thermocouple is electrically insulated from the heater. The thermocouple output passes through the output connector (B) and the cable assembly (D) to the HFTC jack of the volt-ammeter.



A - Coaxial Input Connector
B - Output Connector
C - Cylindrical Shield
D - Cable Assembly
G - Galvanometer
H - Heater
R - Film Resistor
RFC - Isolation Chokes
T - Thermocouple
TC - Thermal Converter

Figure 11. HFTC Circuit

20. The output of the thermocouple is balanced against an adjustable EMF that is varied by the NO. 1 controls (16 and 18, figure 14). Balance is indicated by the internal galvanometer (19). The GALV SELECTOR switch (22) is set to the EXT position to connect the galvanometer to the HFTC circuit. After the NO. 1 controls have been manipulated to produce a balance on the galvanometer, the radio frequency voltage source is removed from the input and an adjustable DC or audio frequency source of approximately the same magnitude is substituted. The amplitude of this source is then adjusted to restore a null on the galvanometer, indicating that the new voltage has been made equal to the radio frequency voltage. The DC or audio frequency voltage is then measured, using the volt-ammeter in the conventional manner.



A - Coaxial Input Connector
B - Output Connector
C - Cylindrical Shield
H - Heater
R - Film Resistor
T - Thermocouple
TC - Thermal Converter
S1 and S2 - Internal Shields

Figure 12. High Voltage HFTC Construction

21. Two types of construction are required for HFTC's to cover the voltage ranges from 0.6 to 200 volts. The four lowest ranges (to 20 volts) consist of a single resistor in a cylindrical shield as shown in Figure 11. The higher ranges (50 to 200 volts) are constructed as shown in Figure 12. Two resistors are used, and each resistor has its own internal shield (S1 and S2). S1 is connected to the input potential, and S2 is grounded. The position of S2 is adjusted axially during calibration to produce a minimum frequency response error.

22. OPERATING INSTRUCTIONS.

23. Operating instructions contained in this manual are for different measurements which can be made with the volt-ammeter. Operating instructions are divided into: AC voltage measurements, DC voltage measurements, AC or DC current measurements, AC - DC difference testing, calibrating an AC source to a specified value and measurement of radio-frequency voltage. To avoid damaging the volt-ammeter follow the operating instructions contained in this manual.

24. Figure 14 shows all the volt-ammeter operating controls. Figure 15 lists the functions of all switches and controls. Figure 16 lists the function of the indicating meters. Figure 17 lists the function of the various terminals. The operator should be thoroughly familiar with the location and function of all switches, controls, meters, and terminals before using the volt-ammeter. Be sure that the shorting link is connected between terminals M (24 and 25, figure 14) except when measuring AC - DC differences.

25. Neither of the POTR terminals (13 and 14, figure 14) is to be grounded. If RF interference is troublesome in that it makes the potentiometer readings erratic, connect a capacitor (approximately 0.05 UF) from one of the POTR terminals to the GRD (30, figure 14) terminal.

26. Each range can be used from the maximum value indicated on the range switch to 40 percent of the maximum value. For instance, the 150 volt scale can be used from a minimum of 60 volts to the maximum of 150 volts.

27. A panel meter is provided to indicate the amount of current flowing in the thermal converter heater circuit. In order to avoid a burnout of the heater, the transfer selector switch (11) should always be placed in the RECT INST position until the proper setting of the voltage or current range switch has been made. When the correct range has been chosen the panel meter will show an indication in the calibrated portion of its scale. Placing the transfer selector switch in the RECT INST position disconnects the heater and substitutes the panel meter instead. The resistance of the panel meter is equal to the resistance of the heater; therefore, substitution of this meter does not alter the flow of current and the panel meter accurately indicates the magnitude of heater current. The panel meter has been calibrated so that full-scale indication corresponds to 7.5 MA AC, which is the normal maximum operating value of heater current. The maximum continuous heater current is rated at 10 MA. Thus a reading on the calibrated portion of the scale of the panel meter always indicates that the current is in the safe operating range of the thermal converter heater.

28. On most ranges, the reading of the panel meter can be used for approximating the setting of the external potentiometer. However, the panel meter cannot be used accurately for this purpose on the 6, 3 and 1.5 volt ranges, or on the 50 and 25 MA ranges. This is because the meter causes appreciable loading of the shunts and multipliers on these ranges. Due to this loading, the panel meter will not indicate full scale on these ranges when the voltage or current value indicated by the range switch is applied. No harm will result to the heater if voltages or currents exceeding the values indicated by the range switch are applied providing they do not exceed the full-scale deflection of the panel meter. If the panel meter reads near the high end of its scale, however, it may be impossible to obtain a balance in the NO. 2 position because the current or voltage exceeds the value shown on the range switch. In this case the input voltage or current should be reduced until it is less than the value shown by the range switch or the range switch should be advanced to the next higher range. The panel meter indications shown in figure 13 may be used to achieve the full-scale values indicated by the range switch.

Range	Panel Meter		Approx. Potr. Setting
	Reading	Scale	
50 MA	.43V	.5V	.5V
25 MA	.39V	.5V	.5V
7.5 MA	1.5V	1.5V	1.5V
6V	1.34V	1.5V	1.5V
3V	1.26V	1.5V	1.5V
1.5V	1.08V	1.5V	1.5V
0.5V	.50V	.5V	.5V

Figure 13. Panel Meter Indications

The readings taken on the potentiometer will not reflect the errors shown by the panel meter as compensation has been provided in the transfer circuit to maintain the rated accuracy of .05%.

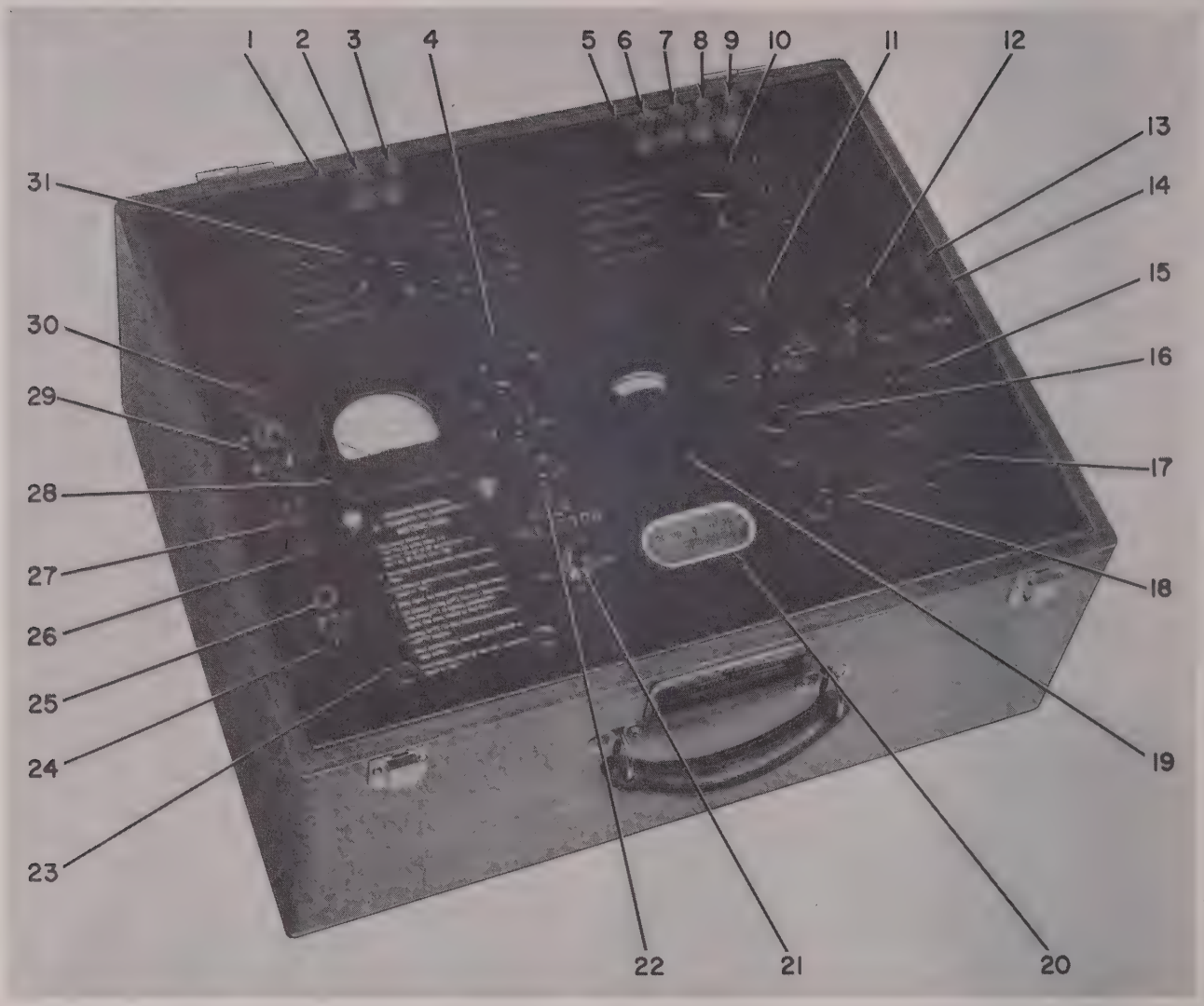
29. The potentiometer settings corresponding to these spans are:

Voltage ranges: 1500 volts down to 1.5 volts. Potentiometer reads 1.5 to 0.6 volts. 0.5 volt range, potentiometer reads 0.5 to 0.2 volts.

Current ranges: 25 amperes down to 25 milliamperes. Potentiometer reads 0.5 to 0.2 volts, 7.5 milliamperes range. Potentiometer reads 1.5 to 0.6 volts.

CAUTION

The volt-ammeter can be operated at potentials that are hazardous to human life. The operator should observe the standard safety precautions. The volt-ammeter should not be operated unless one of the black input terminals (1 or 5, figure 14) or the silver GRD terminal (30, figure 14) has been grounded.



1. VOLT V - Terminal
2. VOLT TO 600 V Terminal
3. VOLT 1500 V Terminal
4. Function Selector Switch
5. AMPERES I- Terminal
6. AMPERES TO 5A Terminal
7. AMPERES 10A Terminal
8. AMPERES 25A Terminal
9. AMPERES EXT SHUNT Terminal
10. Current Range Switch
11. Transfer Selector Switch
12. Battery Switch
13. POTR + Terminal
14. POTR Terminal
15. COARSE ADJ NO. 2 Control
16. COARSE ADJ NO. 1 Control
17. FINE ADJ NO. 2 Control
18. FINE ADJ NO. 1 Control
19. Galvanometer
20. Galvanometer Optical Vernier
21. GALV SENS Switch
22. GALV SELECTOR Switch
23. Condensed Instruction Plate
24. Milliammeter M Terminal
25. Milliammeter M+ Terminal
26. EXT GALV Terminal
27. EXT GALV Terminal
28. Panel Meter
29. HFTC Jack
30. GRD Terminal
31. Voltage Range Switch

Figure 14. Front Panel, Volt-Ammeter

Figure 14 Index No.	Switch Name	Function
4	Function Switch	Selects volt-ammeter circuits for AC voltage when positioned at AV, AC or DC current when positioned at AC - DC, or DC voltage when positioned at DV.
31	Voltage Range Switch	Switches multipliers into the circuit to reduce the voltage to be measured.
10	Current Range Switch	Switches shunts into the circuit to reduce the current to be measured.
11	Transfer Switch	Selects which current will heat thermal converter (RECT INST connects panel meter for determining range, NO. 1 TC-AC position selects AC or DC voltages or currents to be measured, NO. 2 DC REV POL position selects internal batteries with reversed polarity).
12	Battery Switch	Connects the internal batteries into the circuit.
21	GALV SENS Switch	Shunts galvanometer for LO sensitivity and shorts galvanometer in normally-off position.
16	COARSE ADJ NO. 1 Control	A variable resistor which controls the voltage from one of the internal batteries. This voltage nulls the voltage from the thermocouple and acts as a memory or reference while transferring to the second battery voltage.
18	FINE ADJ NO. 1 Control	A variable resistor which is a vernier for the COARSE ADJ NO. 1 control.
15	COARSE ADJ NO. 2 Control	A variable resistor which controls the voltage from the internal batteries used to heat the thermocouple and match the proportional voltage or current being measured which heated the thermocouple in the NO. 1 position.
17	FINE ADJ NO. 2 Control	A variable resistor which is a vernier for the COARSE ADJ NO. 2 control.
22	GALV SELECTOR Switch	Connects either the internal galvanometer or, if being used, an external galvanometer.

Figure 15. Switch and Control Functions

Figure 14 Index No.	Nomenclature	Function
28	Panel Meter	Will deflect in calibrated portion of dial when range switch is in correct position.
19	Galvanometer	Indicates when a coarse balance exists.
20	Galvanometer Optical Vernier	This indicator is a vernier for the galvanometer when a precise balance exists.

Figure 16. Indicating Meter Functions

Figure 14 Index No.	Terminal Name	Function
1	VOLT V-Terminal	Black voltage input terminal connects input voltages for all ranges. This terminal must be at ground potential.
2	VOLT TO 600V Terminal	Red voltage input terminal connects input voltages up to 600 volts.
3	VOLT 1500V Terminal	Red voltage input terminal connects only 1500 volts.
5	AMPERES I-Terminal	Black current input terminal connects input currents for all ranges. This terminal must be at ground potential.
6	AMPERES TO 5A Terminal	Red current input terminal connects input current up to 5 amperes.
7	AMPERES 10A Terminal	Red current input terminal connects input currents up to 10 amperes.
8	AMPERES 25A Terminal	Red current input terminal connects input currents up to 25 amperes to the range switch.
9	AMPERES EXT SHUNT Terminal	Red terminal connects external 500 millivolt shunts.
13	POTR + Terminal	The positive terminal for connecting the external potentiometer.
14	POTR Terminal	The second terminal for connecting the external potentiometer.
25	Milliammeter M+ Terminal	The positive terminal for connecting the milliammeter used in AC - DC difference tests.
24	Milliammeter M Terminal	The second terminal for connecting the milliammeter.
26 and 27	EXT GALV Terminal	Two terminals for connecting a galvanometer of higher sensitivity than the internal galvanometer. Used for AC - DC difference tests.
29	HFTC Jack	High frequency thermocouple jack which connects an external thermocouple when measuring RF voltages.
30	GRD Terminal	The ground terminal used to ground the case and panel only when the voltage or current being measured is not grounded.

Figure 17. Terminal Functions

30. MEASURING AC VOLTAGES (figure 14).

a. Set voltage range switch (31) to 600 V unless 1500 V range is to be used.
b. Set function selector switch (4) to AV.
c. Set GALV SELECTOR switch (22) to INT.
d. Set transfer selector switch (11) to RECT INST.
e. Connect the potentiometer to the POTR terminals (13 and 14). Observe the polarity marking next to the POTR terminals.
f. Connect the leads from the voltage to be measured to the proper input terminals. If this voltage is grounded at source, connect the grounded lead to the black terminal (1). If the voltage is not grounded a separate ground lead must be connected to the GRD terminal (30).
g. Set battery switch (12) to ON.
h. Observe the panel meter (28). If there is no deflection or very slight deflection turn the voltage range switch (31) downscale until the panel meter has a deflection in the calibrated portion of the scale.
i. Set the potentiometer to approximately the reading on the panel meter.
j. If necessary zero the galvanometer pointer with the knob just below the pointer.
k. If necessary a fine adjustment of the light-beam zero can be made by sliding the glass scale sideways.
l. Set the transfer switch (11) to NO. 1.
m. Set the GALV SENS switch (21) to LO.
n. With the COARSE ADJ NO. 1 control (16) null the galvanometer (19).
o. Set the GALV SENS switch (21) to HI.
p. With the FINE ADJ NO. 1 control (18) null the galvanometer vernier (20).

NOTE

A careful and precise null must be obtained to assure an accurate measurement.

q. Set the transfer selector switch (11) to NO. 2.
r. Set the GALV SENS switch (21) to LO.
s. With the COARSE ADJ NO. 2 control (15) null the galvanometer (19).
t. Set the GALV SENS switch (21) to HI.
u. With the FINE ADJ NO. 2 control (17) null the galvanometer vernier (20).
v. Balance the potentiometer and record its setting. Multiply the potentiometer reading by the range switch multiplying factor to obtain the magnitude of the voltage which is being measured.
w. Set the battery switch (12) to OFF.

31. MEASURING AC OR DC CURRENTS.

a. Set current range switch (10) to 5 amperes unless the 10 or 25 ampere ranges are to be used, in which case the proper range should be selected.
b. Set function selector switch (4) to AC - DC.
c. Set GALV SELECTOR switch (22) to INT.
d. Set transfer selector switch (11) to RECT INST.
e. Connect the potentiometer to the POTR terminals (13 and 14). Observe the polarity marking next to the POTR terminals.
f. Connect the leads from the current to be measured to the proper input terminals. If this current is grounded at source, connect the ground lead to the black terminal (5). If the current is not grounded a separate ground lead must be connected to the GRD terminal (30).
g. Set battery switch (12) to ON.
h. If the current to be measured is less than 5 amperes observe the panel meter (28). If there is no deflection or very slight deflection turn the current range switch (10) downscale until the panel meter has a deflection in the calibrated portion of the scale.
i. Set the potentiometer to approximately the reading on the panel meter.
j. If necessary zero the galvanometer pointer with the knob just below the pointer.
k. If necessary a fine adjustment of the light-beam zero can be made by sliding the glass scale sideways.
l. Set the transfer switch (11) to NO. 1.
m. Set the GALV SENS switch (21 to LO.
n. With the COARSE ADJ NO. 1 control (16) null the galvanometer (19).
o. Set the GALV SENS switch (21) to HI.
p. With the FINE ADJ NO. 1 control (18) null the galvanometer vernier (20).

NOTE

A careful and precise null must be obtained to assure an accurate measurement.

q. Set the transfer selector switch (11) to NO. 2.
r. Set the GALV SENS switch (21) to LO.
s. With the COARSE ADJ NO. 2 control (15) null the galvanometer (19).
t. Set the GALV SENS switch (21) to HI.
u. With the FINE ADJ NO. 2 control (17) null the galvanometer vernier (20).
v. Balance the potentiometer and record its setting. Multiply the recorded potentiometer reading by the range switch multiplying factor to obtain the magnitude of the current which was measured.
w. Set the battery switch (12) to OFF.

32. MEASURING DC VOLTAGES.

NOTE

It is not necessary to turn on the battery switch for DC voltage measurements. Do not use the 0.5V and 1.5V ranges on DC. Measure these voltages directly with the potentiometer.

a. Set the FUNCTION switch (4) to DV.
b. Connect the potentiometer to the POTR terminals (13 and 14). Observe the polarity next to the POTR terminals.
c. Set the voltage range switch (31) to the appropriate range.
d. Connect the leads from the DC voltage to be measured to the proper terminals.
e. Balance the potentiometer and record its setting. Multiply the recorded potentiometer reading by the range switch multiplying factor to obtain the magnitude of the voltage which was measured.

33. SETTING AN AC CALIBRATION SOURCE TO A SPECIFIED VALUE.

a. Connect the potentiometer to the POTR terminals

(13 and 14, figure 14), being sure to observe the polarity marking.

b. Set the function switch (4) to either the AV or AC - DC position depending on whether the source is current or voltage.

c. Set the range switch (10 or 31) to the proper range.

d. Set the transfer selector switch (11) to RECT INST.

e. Set battery switch (12) to ON.

f. Connect the leads from the source to be calibrated to the proper input terminals. If the source is grounded connect the ground lead to one of the black terminals. If the source is not grounded connect a separate ground lead to the GRD terminal (30).

g. Divide the value of the desired calibration voltage or current by the multiplying factor scribed on the panel next to the range switch. Set the potentiometer dials to exactly the value obtained.

h. By checking the panel meter (28) adjust the source until the approximate value which is found in g is shown.

i. Set the transfer switch (11) to position 2.

j. Adjust the NO. 2 COARSE ADJ and FINE ADJ (15 and 17) for a null on the potentiometer.

k. Without rotating the transfer selector switch, adjust the NO. 1 COARSE ADJ and FINE ADJ (16 and 18) controls to obtain a null on the internal galvanometer.

NOTE

A careful and precise null must be obtained if the highest accuracy of measurement is to be achieved. If necessary, prior to balancing, the mechanical zero of the pointer section can be adjusted with the knob just below the pointer. A fine adjustment of the light-beam zero can be made by sliding the glass scale sideways.

l. Set the transfer selector switch (11) to NO. 1 position.

m. Place the GALV SENS switch (21) to LO and adjust the amplitude of the source for a null on the galvanometer. Then place the GALV SENS switch (21) to HI and make a final adjustment of the calibration source to produce a null on the galvanometer. The desired value of voltage or current has now been achieved.

n. Set the battery switch (12) to OFF when finished.

34. MEASUREMENT OF AC - DC DIFFERENCE. Since the shunts and multipliers of the volt-ammeter have been designed to have small AC - DC differences, provisions have been incorporated to use these shunts and multipliers in the testing of AC - DC differences of other instruments. The shunts, multipliers and the thermal converter can be assumed to have a zero AC - DC difference over a wide frequency range.

a. Connect the external galvanometer and the potentiometer to the EXT GALV and POTR terminals. Connect the milliammeter to terminals M.

b. Set the GALV SELECTOR switch (22) to INT.

c. Set the function switch at the proper position. Set at AV for voltage, or at AC for current, the range switch on the proper range, and the transfer selector to NO. 1.

d. Connect a reversible DC source and the instrument to be tested to the input terminals.

e. Set the battery switch (12) to ON.

f. Adjust the DC source to produce a full-scale deflection on the instrument under test.

g. Calibrate the scale of the external galvanometer in the following manner:

(1) Balance the NO. 1 COARSE ADJ (16) and FINE AND (18) controls to produce a null on the internal galvanometer.

(2) Set the GALV SELECTOR switch to EXT and use the NO. 1 FINE ADJ control to achieve a balance on the external galvanometer.

CAUTION

The GALV SENS (21) switch does not control the sensitivity of the external galvanometer. Therefore, the GALV SELECTOR switch (22) should be returned to the INT position before any large change in input voltage or current is made. Failure to turn off the external galvanometer may damage it.

(3) Decrease the value of the DC source by 0.5 percent. This decrease can be measured by observing the scale of the instrument under test or by using the procedure of paragraph 33.

(4) Observe and record the deflection produced on the external galvanometer by the 0.5 percent change. Obtain the scale factor of the external galvanometer by dividing 0.5 percent by the number of divisions of deflection.

(5) Record the reading of the milliammeter. In future tests it will not be necessary to redetermine the sensitivity of the external galvanometer provided that the same milliammeter reading is achieved by setting the NO. 1 controls, and the thermal converter has not been replaced. Set GALV SELECTOR switch to INT.

h. Reverse the DC source and adjust it for full-scale deflection of the test instrument. Place the GALV SELECTOR switch on EXT and record the deflection of the external galvanometer. Record the average of the two external galvanometer readings for direct and reversed current. Return GALV SELECTOR switch to INT.

i. Substitute an AC source of the desired frequency for the DC source. Adjust its amplitude to again produce a full-scale deflection of the test instrument. Set the GALV SELECTOR switch to EXT and record the galvanometer deflection.

j. The AC - DC difference can be computed from the difference in the AC and average DC galvanometer deflections, applying the scale factor determined in step g.

35. USING HFTC's. When using an HFTC (see figure 4 and 5), observe the following precautions.

a. The accuracy of measurements made at high frequencies will depend on the proper connection of

radio frequency circuitry. Volt-meters connected by long lengths of transmission line will not all have identical readings due to standing waves generated in the transmission lines. Most volt-meters, as well as the HFTC's, have relatively high impedances and represent practically open circuits when compared with the characteristic impedances of ordinary transmission lines. Therefore, the HFTC and any volt-meter or circuit point under test must be connected by the shortest possible leads. The lead length should not exceed one inch at frequencies of 30 megacycles if serious errors are to be avoided. If longer lead lengths must be used, then these lengths should be matched when testing voltmeters.

b. Any severe overload of an HFTC may cause a short circuit or a low impedance leakage path between the heater and the thermocouple. This path will cause large errors at high frequencies. The resistance between either of the output pins and the shell of the connector should be checked with an ohm-meter periodically. The resistance should also be checked after any overload. Any reading less than 5 megohms indicates a faulty converter, and the HFTC should be taken out of service.

c. A radio frequency source of practically pure sine waveform must be used for all tests made with the HFTC's. Poor waveform means that higher frequencies are present that may exceed the 30 megacycle rating of the HFTC's. Poor waveform will also cause errors in the readings of rectifier or electronic voltmeters that are being calibrated.

d. The connectors on each end of the cable which connect the HFTC to the volt-ammeter must be screwed down tightly, as the common shield connection is made through the shells of these connectors.

e. Overloads greater that 50% of rated voltage should never be applied to the HFTC's. However, momentary overloads up to 50% will not cause damage.

36. Calibrating Radio Frequency Voltmeters connect the equipment as shown in figure 18. Refer to figure 5 to select the proper HFTC. Sources S1 and S2 (figure 18) must be of approximately equal amplitude.

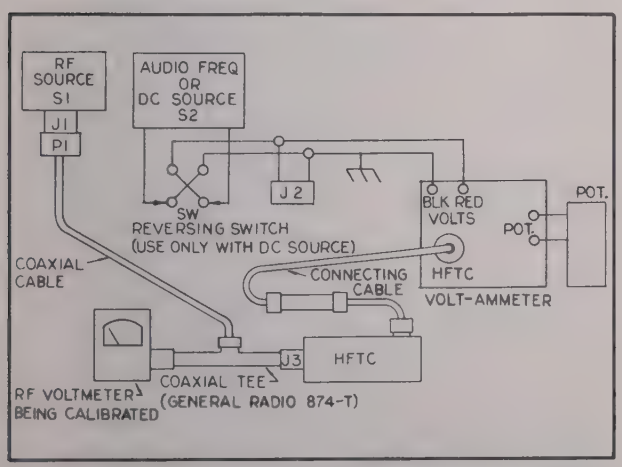


Figure 18. Test Diagram for Calibrating Radio Frequency Voltmeters

37. Set the volt-ammeter controls as follows:

a. Function switch (4, figure 14) at AV for audio voltage or at DV for direct voltage.
b. Voltage range switch (31) at the range that includes the value of radio frequency voltage being used for calibration.
c. OFF-ON switch (12) at ON.
d. GALV SELECTOR switch (22) at EXT.

38. Adjust the amplitude of the radio frequency source to produce a deflection of the voltmeter being tested to the desired scale point.

39. Use the NO. 1 COARSE (16) and FINE (18) controls and the GALV SENS switch (21) on the volt-ammeter to produce a good null on the galvanometer.

40. Move Plug P1 to J2.

41. For audio frequency source, adjust the amplitude of the audio frequency source (S2) to produce a null on the volt-ammeter's galvanometer. This equates the amplitude of the audio frequency voltage to the radio frequency voltage. Then set the GALV SELECTOR switch at INT and measure the audio-frequency voltage in the normal manner with the volt-ammeter and the potentiometer.

42. For DC source, adjust the amplitude of the DC source to produce a null on the volt-ammeter's galvanometer. This equates the amplitude of the DC voltage to the radio frequency voltage. Balance the potentiometer and record its reading. Operate the reversing switch SW (figure 18) to its opposite position and again adjust the amplitude of the DC source S2 to obtain a null on the volt-ammeter's galvanometer. Balance the potentiometer and again record its reading. Compute the average of the two potentiometer readings and multiply the average value by the factor given on the range switch to obtain the actual value of voltage.

43. MEASUREMENT OF RADIO FREQUENCY VOLTAGE.

a. Connect the equipment as shown in figure 18. However, omit the coaxial cable and coaxial tee and connect J3 directly to the radio frequency source at J1.
b. Set the volt-ammeter controls as in paragraph 37.
c. Repeat paragraph 39.
d. Move J3 to connect with J2.
e. Follow paragraph 41 or 42 to determine the value of voltage being measured.

44. To determine the frequency response of radio-frequency volt-meters, follow steps a through e, below.

a. Connect the equipment as shown in figure 18, omitting the audio frequency or DC Source (S2).
b. Set the volt-ammeter controls as in paragraph 37.
c. Determine the sensitivity of the galvanometer in the following manner: Set the frequency of the radio frequency source at any low frequency that is known to lie in the flat frequency response range of the meter under test. Adjust the amplitude of the source to produce a deflection of exactly full scale on the meter

under test. Balance the NO. 1 COARSE and FINE controls. Then vary the amplitude of the source by a known increment and observe and record the deflection of the galvanometer and compute the galvanometer sensitivity. Readjust the source amplitude to again produce a null indication on the galvanometer.

d. Increase the frequency of the radio frequency source to the point desired for the frequency response test.

e. Adjust the amplitude of the source to again produce a full-scale deflection on the meter under test. Depress the galvanometer key on the volt-ammeter and note the deflection of the galvanometer. Use the galvanometer sensitivity determined in step c, above to determine the frequency error of the meter under test.

45. MAINTENANCE INSTRUCTIONS.

46. The maintenance instructions contained in this manual are divided into three main parts: troubleshooting, replacement of defective parts, and calibration. Troubleshooting will isolate the malfunction to a defective part or parts. There are a number of parts in the volt-ammeter which are not easily replaceable because of special considerations at the time of installation. Some of these parts are discussed in the following paragraphs. Replacement of defective parts describes the procedures for replacing defective parts. Calibration outlines precisely the steps required to restore and check the accuracy.

47. TROUBLESHOOTING.

48. Most difficulties with the volt-ammeter can be classified into two groups which are: drifting or erratic operation, which makes it difficult to make precise readings, and normal operation, but inaccurate results.

49. DRIFT AND ERRATIC OPERATION. When there are rapidly changing potentiometer readings making accurate readings impossible the malfunction could be in the COARSE ADJ and FINE ADJ NO. 2 controls or the associated circuits. If the drift exceeds 0.02 percent per minute or if the drift is in the galvanometer indications, replace mercury cell pack (1, figure 25).

50. If the potentiometer indications are erratic the trouble or malfunction could be either in the COARSE ADJ and FINE ADJ NO. 2 controls or radio frequency interference. The COARSE ADJ and FINE ADJ NO. 1 and NO. 2 may be noisy due to oxidation of the contracts. The trouble may be eliminated by rotating the controls through their entire range a few times. If this does not clear the trouble the defective variable resistor should be replaced.

51. Radio interference may be picked up by the volt-ammeter through either the input being measured or through the potentiometer circuit. The interference becomes evident due to the volt-ammeter's extended frequency response. There is an internal RF filter in the volt-ammeter, but to further reduce the interference a 0.01 microfared capacitor can be connected between one of the POTR terminals and the GRD terminal. Also the black input terminal should be connected to an earth ground.

52. A third possible cause of drift and erratic operation could be thermal converter leakage. To check for thermal converter leakage proceed as follows:

a. Remove the thermal converter as described in paragraph 59.

CAUTION

The ohmmeter to be used in the following measurements must be a high impedance instrument. For the measurement in step b the test current must not exceed 7.5 milliamperes. For the measurement in step c the test current must not exceed 10 milliamperes. A higher current will damage the thermal converter.

b. Check the heater resistance between the black and gray terminals. The resistance should be approximately 67 ohms.

c. Check the thermocouple resistance between the red and green terminals. The resistance should not exceed 25 ohms.

CAUTION

The ohmmeter voltage used for the measurement in step d should not exceed 10 volts. Greater voltages may damage the thermal converter.

d. Check for leakage between the heater and the thermocouple by checking the resistance between the red and gray terminals. The resistance should be at least 50 megohms.

53. INACCURATE TEST MEASUREMENTS. The difficult part of this malfunction is establishing that the test measurements are inaccurate. If it is suspected that the measurements are inaccurate a preliminary check would be to perform the entire calibration procedure. If a switch or the galvanometer could be at fault replace the part. The shunts and multipliers are made of manganin and will not change their value unless they have been subjected to serve overloads. Damage to the shunts and multipliers may not be visible, but if the malfunction is isolated to them the volt-ammeter should be returned to the factory if possible. If not, replacement of the defective part should be made as described in paragraph 58. All shunts and multipliers are hand-fitted to the individual volt-ammeter, and replacing one shunt multiplier will disturb the total impedance of the circuit unless recalibration is performed. There is a chance that a defective thermal converter (leakage) could cause the malfunction. Replace the thermal converter or test it as described in paragraph 52.

54. FAULTY HFTC. Large frequency response errors, are caused by leakage or a short circuit between the heater and the thermocouple. Connect an ohmmeter with a measuring voltage of less than 25 volts between either of the pins of the output connector and the shell of the connector. The reading should be at least 5 megohms.

55. Low sensitivity can be tested by applying the rated input voltage to the HFTC in question. Either DC or audio frequency current may be used. The output voltage is measured with a potentiometer and should be greater than 5.0 millivolts DC. Low output may be a result of an overload, or it may be due to leakage of the vacuum in the thermal converter.

56. In order to check for erratic operation, the HFTC input should be connected to a stable DC or AC source. The voltage of this source should be adjusted to equal the maximum rated voltage of the HFTC. The volt-ammeter controls should be set as in paragraph 37. Allow several minutes warmup time. Use the NO. 1 COARSE and FINE controls to obtain a null on the volt-ammeter galvanometer. Hold the GALV SENS key in the HI position and observe the galvanometer. The galvanometer should not move in an erratic manner, and should not drift at a rate greater than three divisions (approximately 0.2%) per minute.

57. If any of the three tests above indicate a faulty HFTC, then that particular unit should be returned to the factory for servicing. It is not possible to replace components of an HFTC in the field. This is because the components and their physical positioning both affect the frequency response, and it is necessary to test the frequency response of the completely assembled HFTC. This test cannot be performed without the use of National Bureau of Standards certified radio frequency standards.

58. REPLACEMENT OF DEFECTIVE PARTS.

59. To replace the lamp battery, mercury cell pack, and thermal converter remove the instruction plate by removing the four thumb screws. This exposes the three parts. To replace the lamp battery just remove the old size D cell and replace with a new one. To replace the mercury cell pack, unsolder the old cell and, observing the color coded leads, solder the leads of the new battery to the color coded lugs of the battery compartment. To replace the thermal converter unsolder the leads and, observing the color code, replace the new thermal converter. Make sure that the spring washer is replaced. Note that when replacing the thermal converter it is not necessary to recalibrate the volt-ammeter.

60. To replace the switches, panel meter or any of the other parts remove the four screws from the bottom of the wooden case and then lift the entire panel and assembly from the wooden case. All the parts are then readily accessible for examination, testing and, if necessary, replacement. There are no unusual procedures required to replace the parts. When disconnecting the leads from the part they should be tagged and connected in the same location and manner. Avoid overheating of leads and parts such as resistors, because overheating may change their value, thus altering the calibration.

61. CALIBRATION.

62. The accuracy of the volt-ammeter is checked using DC voltage or current from a stable source. The DC is connected to the proper input terminals and is measured by the volt-ammeter as accurately as possible. Polarity is then reversed with the same source and measured again. The two readings are averaged and the average reading is compared with a standard volt box or shunt. Calibration accuracy is now known for all DC measurements and holds for AC measurements up to approximately 10 kilocycles. Above 10 kilocycles the accuracy decreases but remains within the tolerance of 0.05 percent. Exact calibration accuracy above 10 kilocycles for AC - DC difference tests must be performed by the National Bureau of Standards. The test equipment required to perform the DC calibration is listed in figure 19.

63. Before starting the test procedure certain requirements and precautions should be understood by the technicians who will perform the calibration procedures. Since the volt-ammeter is an extremely accurate test instrument the calibration procedure is precise, and failure to adhere to the following requirements and precautions should lead to erroneous readings and the assumption that the volt-ammeter is not accurately calibrated.

64. It is recommended that output voltage from the shunts and volt box ranges be equivalent to the ranges of the volt-ammeter. The advantage of equivalent voltages is that it will not be necessary to adjust that potentiometer, or range switch, thereby reducing the effect of potentiometer errors. Also, if a potentiometer such as the Leeds & Northrup K-3 is used, then the manufacturer's recommendation that a capacitor be connected between the case and ground should be followed. The case should never be directly grounded.

65. When connecting the potentiometer to the test equipment, especially to the volt box, short low resistance leads must be used. The GRD terminal on the volt-ammeter or the low voltage end of the volt box must be grounded.

66. Basically two technicians are needed to perform the calibration procedures; one to adjust and read potentiometer controls and the second to adjust the volt-ammeter.

67. The thermal converter has an extremely wide frequency response and television, broadcast and other RF transmission can cause the volt-ammeter to give erroneous measurements. A check for this type of interference can be made as follows:

a. Connect volt-ammeter in normal measuring method, but do not energize source to be measured.
b. Set the transfer selector switch (11, figure 14) to NO. 1.
c. Adjust the COARSE ADJ and FINE ADJ NO. 1 controls for minimum galvanometer deflection.

Nomenclature	Part Number of Model	Application	Range	Accuracy
Volt-box	Rubicon Cat. No. 2794 or equal	voltage calibration	3.0, 7.5, 15, 30, 75, 150, 300, 750 volts	NBS certified to 0.01%
Regulated D.C. Power Supply	Kepco Model 1520B or equal	voltage calibration power supply	0-1500 volts	0.01% regulation
Potentiometer	Rubicon Type B or equal	voltage and current calibration	0-1.61 volts	0.01% or 30 microvolts whichever is greater
Double Pole Switch	Leeds & Northrup Cat. No. 3294 or equal	voltage and current calibrations. Potential selector and reversing switches		
Shunt Resistors (4 terminal)	0.01 ohm, 25 amp Rubicon Cat. No. 1151 or equal	current calibration		certified to 0.01% at 10, 25 amp
	0.1 ohm, 5 amp Rubicon Cat. No. 1152 or equal	current calibration		certified to 0.01% at 1, 2.5, 5 amp
	1 ohm, 0.5 amp Rubicon Cat. No. 1160 or equal	current calibration		certified to 0.01% at 0.5, 0.25, 0.1 amps
	10 ohms, 0.05 amp Rubicon Cat. No. 1101 or equal	current calibration		certified to 0.01% at 0.05, 0.025 amps
	100 ohm, 10 ma Rubicon Cat. No. 1102 or equal	current calibration		certified to 0.01% at 0.0075 amps
Current Power Supply	North Hills Electric Co. Cat. No. CG 12 or equal	current calibration power supply. Use with 6 volt storage battery	0.5 - 30 amps	0.05% regulation
Current Power Supply	North Hills Electric Co. Cat. No. CS 111 or equal	self-contained power supply	7.5 ma to 0.5 amp	0.05% regulation

Figure 19. Equipment Required for Calibration

d. Connect a shorting wire across the input terminals. When the shorting wire is in place there should be no noticeable change in galvanometer deflection.
e. Set the transfer selector switch to the NO. 2 position. Set the NO. 1 coarse control at the middle of its range.
f. With the COARSE ADJ and FINE ADJ NO. 2 controls adjust for a balance on the galvanometer.
g. Connect a capacitor, approximately 0.002 microfarads, across the POTR terminals. There should be no noticeable galvanometer deflection.

68. Before starting the calibrating procedure and after a large change in the potential to be measured there should be a minute or two delay before taking readings. This is to permit the thermal converter to stabilize any small drifts. Normally the drift is insignificant, but for calibration it should be stabilized.

69. VOLTAGE RANGE CALIBRATION. Connect the volt-ammeter as shown in figure 20. Check the calibration of each range at full scale if possible. If the volt-ammeter is being checked at half scale, it is recommended that an external galvanometer be connected as described in paragraph 34. The half scale calibration check is particularly useful on the 1500 volt range because 1500 volt volt boxes are not readily available.

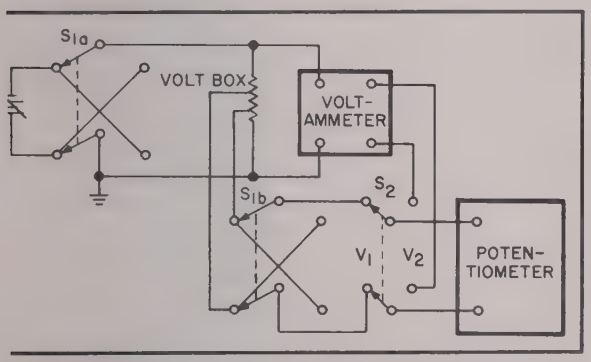


Figure 20. Voltage Range Calibration Test Connections

70. The DC calibration on all voltage ranges should prove to be accurate to within ±0.03 percent of the full scale value. Note that the volt-ammeter accuracy is stated as 0.05 percent. The additional 0.02 percent is the tolerance for AC - DC difference.

71. CURRENT CALIBRATION.

72. Connect the volt-ammeter as shown in figure 21. Check the calibration of each scale with the proper current. The DC calibration accuracy should be accurate within ±0.03 percent of full scale value. The reason for the difference in the tolerance between the ±0.05 percent and the ±0.03 percent is the same as described previously.

RESTORING THE ACCURACY OF INDICATIONS. If the preceding calibration checks indicate errors in one or more ranges it will be necessary to alter the appropriate multiplier resistor or shunt in order to restore the initial accuracy.

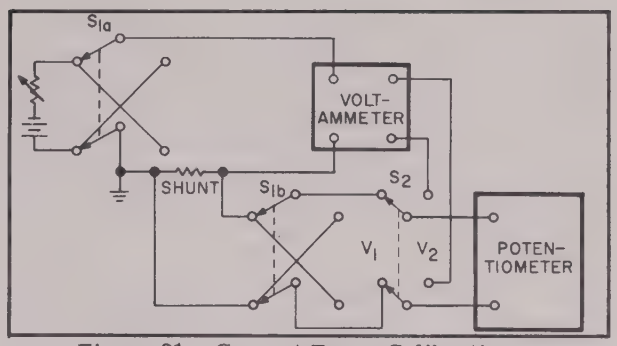
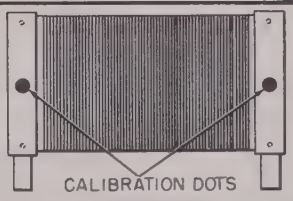


Figure 21. Current Range Calibration Test Connections

74. The multiplier resistors associated with the voltage ranges must be selected to an accuracy of ±0.01 percent in order to match the remainder of the resistors in the multiplier string. The nominal values of resistors are indicated on the schematic diagram, figure 6. The actual value of resistor required will be within the range of the nominal value ±0.05 percent. In the case of the voltage multiplier, the original value of the resistor which is to be replaced can be determined from the color dots painted on both ends at the center portion of the resistor terminal leads. The color dots indicate the deviation from the nominal value specified on the schematic diagram. Figure 22 shows the location of the calibration dot and gives the tolerance.



Color Dot	Deviation from Nominal Value (percent)
Green	+0.05
Yellow	+0.04
Orange	+0.03
Red	+0.02
Brown	+0.01
Black	0.00
White	-0.01
Grey	-0.02
Violet	-0.03
Blue	-0.04
Gold	-0.05

Figure 22. Location of Resistor Color Dots

75. The calibration of the current ranges can be corrected as follows: Ranges: 25, 10, 5, 2.5, and 1 ampere. Carefully file the opening just under the potential lead of the shunt associated with the range that is in error. One opening is designed so that filing will decrease the shunt resistance by shortening the length of the shunt. The other opening can be used to increase shunt resistance. Exercise care while filing to avoid damage to the insulation material adjacent to the openings.

76. The calibration of ranges 500 MA, 250 MA, 100 MA, 50 MA and 25 MA is adjusted by altering the compensating resistor associated with the range to be recalibrated. Care must be taken in altering the compensating resistances as a change in any one range will affect all lower ranges.

77. The calibration of the 7.5 MA range can be corrected by replacing the 200 ohm resistor which is associated with the potential terminals. This resistor should be 200 ohms.

NOTE

When replacing multiplier and shunt resistors the new resistors must be replaced in exactly the same mechanical position as the original resistor in order to minimize changes in the AC - DC difference of the instrument. Do not replace with resistors of a different manufacturer or construction or the AC - DC difference will be affected.

SECTION II

PARTS BREAKDOWN

1. GENERAL. The parts list in this manual identifies the parts which have been authorized as spare parts. The following paragraphs describe what is contained in each of the columns of the parts breakdown.

2. INDEX NUMBER COLUMN. This column lists the figure and the index number on the figure where the part is shown. If the column has been left blank then the part is hidden from view on all the figures and a brief location description is given in the Nomenclature column.

3. PART NUMBER COLUMN. The Part Number column lists the part number of the manufacturer of that particular part. When the work Commercial appears in this column then the part is available from a wide variety of sources.

4. NOMENCLATURE COLUMN. The Nomenclature column lists the name of the part and a description. This column also lists the volt-ammeter manufacturer specification control drawing (SCD) number if the part was purchased and from whom the part was purchased.

Index Number	Part Number	Nomenclature
1-	Model C	AC Transfer Volt-Ammeter, Hermach-Engelhard Model C (FSN 6625-799-5976)
23-1	S-489-64BB-L	KNOB, Switch (Kurz-Kasch, Inc.) (SCD 30083A) (FSN 5355-498-0568)
23-2	Type 938WB	POST, Binding, Black Top and Insulator (Gen. Radio Co.) (SCD 30009A)
23-3	Type 938WR	POST, Binding, Red Top and Insulator (Gen. Radio Co.) (SCD 30010A)
23-4	S-483-64BB-40281	KNOB, Pointer (Kurz-Kasch, Inc.) (SCD 30106A) (FSN 5355-843-1284)
23-5	DF30BC	POST, Binding, 5 Way, Black Top (Superior Electric Co.) (SCD 30019A)
23-6	S-483-64BB-CUT 4	KNOB (Kurz-Kasch, Inc.) (SCD 30084A) (FSN 5355-284-5169)
23-7	1120-A	THUMB SCREW (Cambridge Thermionic Corp.) (SCD 30066A)
23-8	938-L	LINK, Shorting - plated brass (Gen. Radio Co.) (SCD 34878A)
23-9	9760-10	CAP AND CHAIN - receptacle type, 5/8-24, NEF-2A female thd, chain-2-9/16 in. lg (SCD 34749A)
23-10	Type 938P	POST, Binding, Metal - (Gen. Radio Co.) (SCD 30008A)
24-1	31820A	LEVER SWITCH ASSEMBLY (FSN 5930-735-7274)
24-2	3080-AL-SYS	INSERT, Galvanometer (Minneapolis-Honeywell Regulator Co., Industrial Division) (SCD 34814A) (FSN 6625-844-0921)

Index Number	Part Number	Nomenclature
24-3	SP-653-3	FRAMEWORK, Galvanometer - supplied with indicator and indicator clips (Minneapolis - Honeywell Regulator Co., Industrial Division) (SCD 34815A)
24-4	Commercial	POTENTIOMETER - 10 turn operation, 50 ohms ±0.5%, series 205A50 (Borg Equip. Corp.) (SCD 34263A) (FSN 5905-843-3020)
24-5	Commercial	POTENTIOMETER - 3 turn operation, 100 ohms ±5% resistance, 1/2 in. shaft ext., series 205A100 (Borg Equip. Div.) (SCD 30007A) (FSN 5905-843-3021)
24-6	Commercial	POTENTIOMETER - 3 turn operation 1000 ohms ±5% resistance, 1/2 in. shaft ext., linearity ±1%, series 205A1000 (Borg Equip. Corp.) (SCD 34344A) (FSN 5905-843-1283)
24-7	590580	MILLIAMMETER - Rectifier type, range 0-7.5 MA, AC, full scale; range - 20 cycles to 20 KC; resistance - 67 ohms at 25°C (77°F) and 60 cycles (A.C. Weston, Model 301) (SCD 30003A) (FSN 6625-808-9298)
24-8	AN3102A-10SL-4P	CONNECTOR, Electrical, Receptacle - solid shell, 2 contact pins No. 16, 700 V DC, 500 V AC, 22 amps (Amphenol Electronics Corp.) (SCD 34748A)
24-9	SP-228	GLASS, Galvanometer (SCD 34815-4A) (FSN 6625-735-7275)
24-10	SP-232	LAMP, Galvanometer (SCD 34815-4A) (FSN 6625-735-7273)
25-1	302516	CELL PACK, Mercury - 1.34 V DC and 2.68 V DC, with four six-inch lead wires (P.R. Mallory Co., Inc.) (SCD 30004A) (FSN 6625-735-7272)
25-2	30033A	THERMAL CONVERTER ASSEMBLY
25-3	30130A	RING, Retaining
	30107A	SPRING, Compression, Battery Modify No. 1618 (under flashlight battery)
	30266A	SPACER - 1 in. dia x 7/8 in. lg, black felt (between instruction plate and mercury cell pack)
4-	35600C	CABLE, HFTC connecting
5-1	34970-1	CONVERTER, High Frequency Thermal, range 0.6 to 1.4 volts, 5 MA.
5-2	34970-3	CONVERTER, High Frequency Thermal, range 1.2 to 3.0 volts, 5 MA.
5-3	34970-5	CONVERTER, High Frequency Thermal, range 2.0 to 5.0 volts, 5 MA.

Index Number	Part Number	Nomenclature
5-4	34970-10	CONVERTER, High Frequency Thermal, range 4.0 to 10.0 volts, 5 MA.
5-5	34970-20	CONVERTER, High Frequency Thermal, range 8.0 to 20.0 volts, 10 MA.
5-6	34970-50	CONVERTER, High Frequency Thermal, range 20.0 to 50.0 volts, 10 MA.
5-7	34970-100	CONVERTER, High Frequency Thermal, range 40.0 to 100.0 volts, 10 MA.
5-8	34970-200	CONVERTER, High Frequency Thermal, range 80.0 to 200.0 volts, 10 MA.

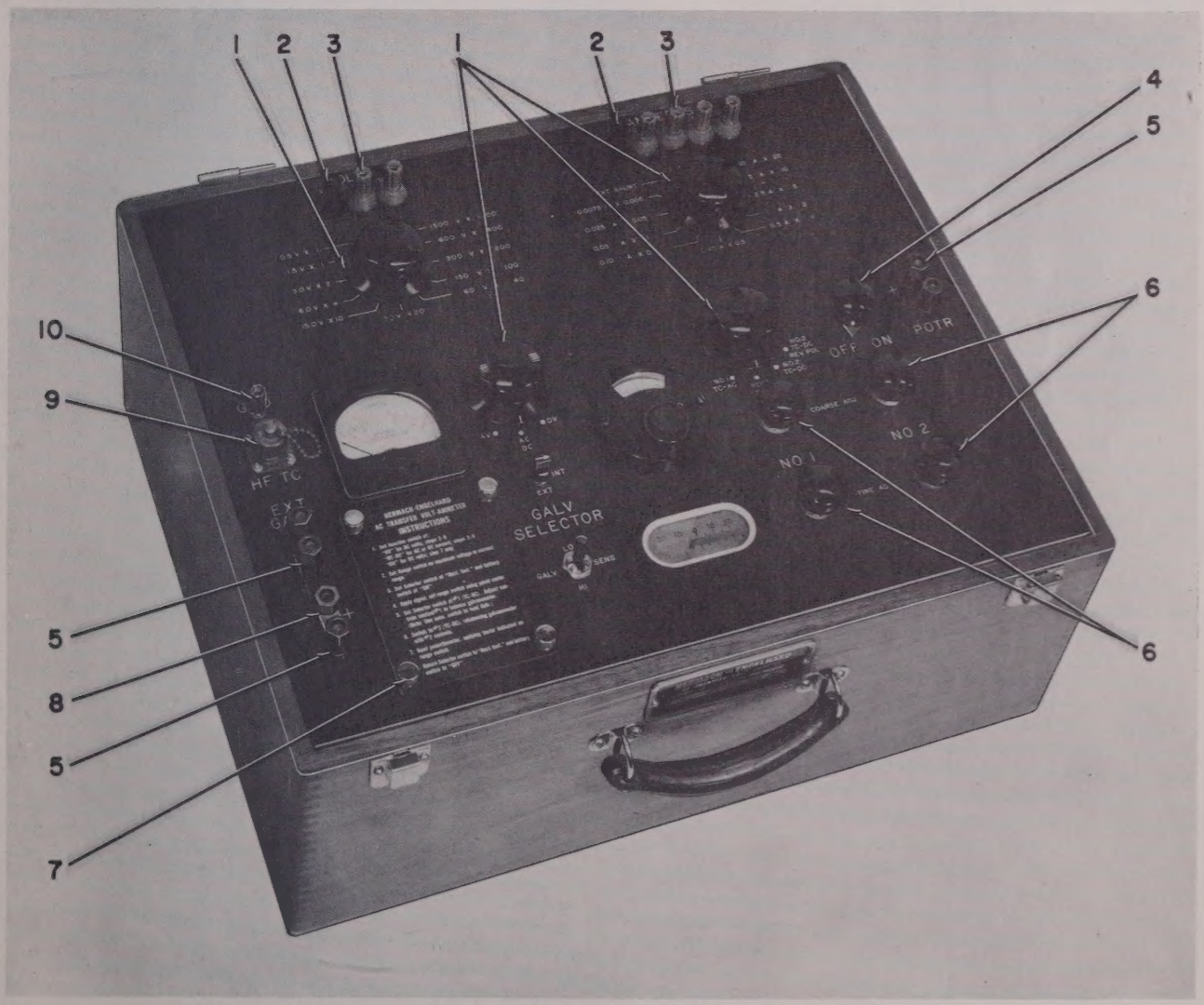


Figure 23. Top View of Components

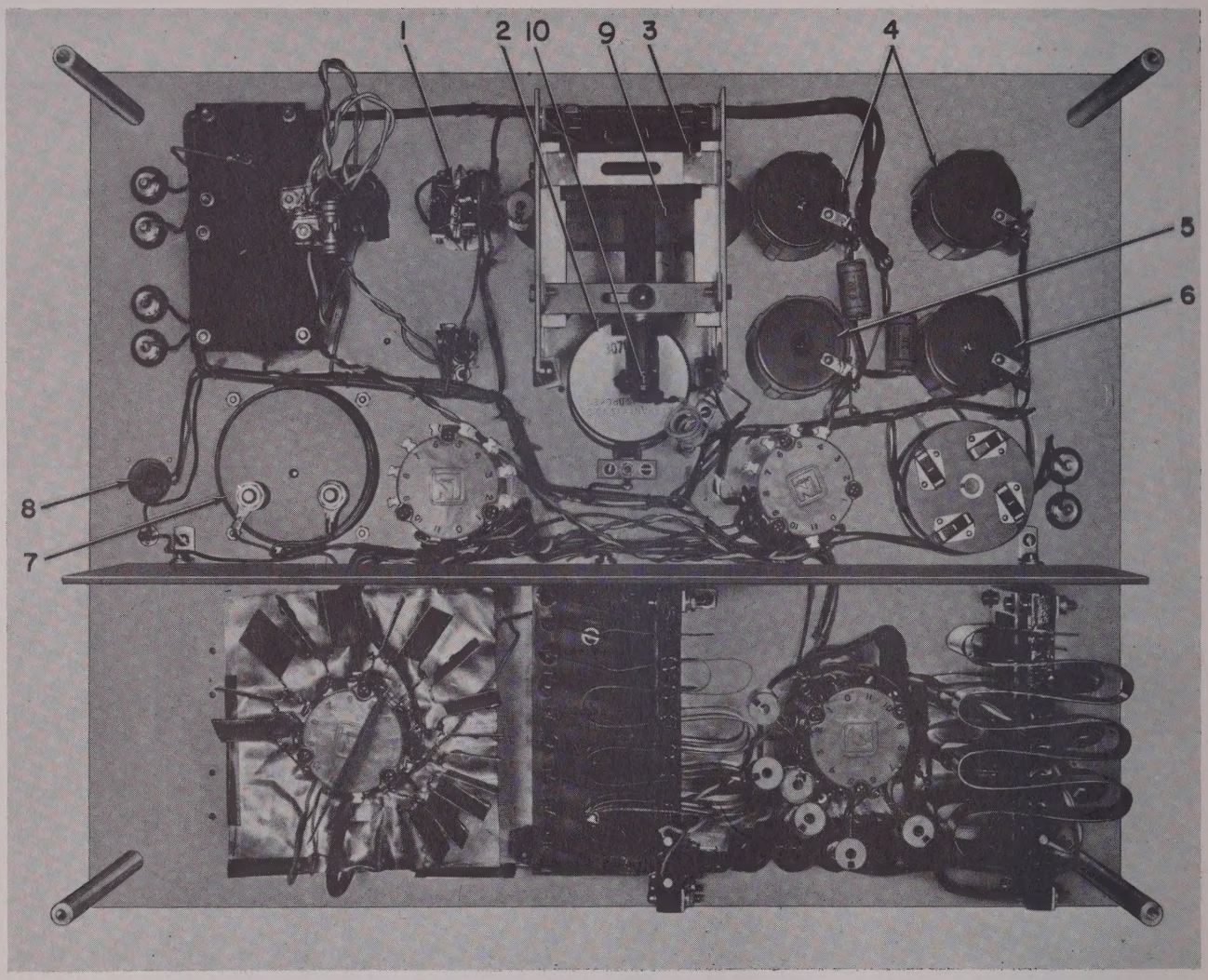


Figure 24. Bottom View of Components

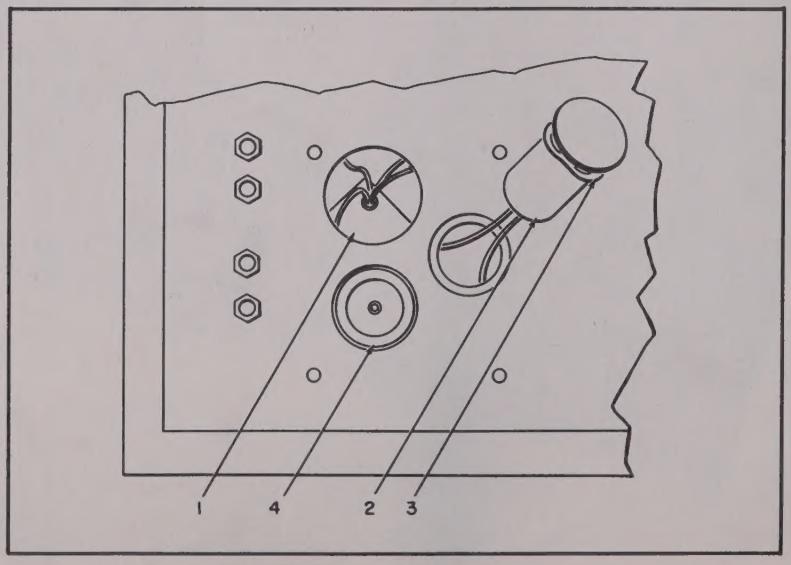


Figure 25. Components Under Instruction Plate

MP MASTER
MA31601

FORM NO. 6200